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SPACE TECHNOLOGY IN BERLIN. VOLUME 1: IDEAS FOR THE
ESTABLISHMENT OF AN INSTITUTE FOR SPACE PROCESSING TECHNOLOGY

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16. Abstract Discusses the past, present, and future status of space technology in Berlin, including raw material processing, transportation, energy, and infor- mation generation and distribution. Indicates how Berlin can contribute toward further advancement in this field, individually or in collaboration with inter- national partners.					
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SPACE TECHNOLOGY IN BERLIN. VOLUME 1: IDEAS FOR THE
ESTABLISHMENT OF AN INSTITUTE FOR SPACE PROCESSING TECHNOLOGY

1. WORK GOALS

/1*

The field of space transportation technology acquires /2
greater meaning in the medium term when viewed within the context
of the politics of technology.

The following constitute actual developments in space
transportation. These developments necessitate the
intensification of all previous transportation efforts:

- The benefits of the European spacelab,
- The establishment, under international cooperation, of a
permanent space station at the beginning of the 1990s,
- The commercialization and further development of European
transport systems (ARIANE, HERMES, HOTOL),
- Soviet developments in manned space transport.

Ways to generate and distribute information on satellites
and space probes are being discovered in an industrial sense in
Berlin. In a similar fashion, the transportation aspect of space
technology is also being discovered. The benefits of space and
other airborne structures for the generation of energy to
manufacture marketable products have, until now, been explored
only in the form of single experiments. In this area, research
on the fundamentals must be carried out systematically and
oriented toward specific applications. This research must be
transferred to industrial production. This field is not
dependent upon location. On the contrary, work in this field,
based on a good scientific infrastructure, can be initiated by
and also carried out in Berlin.

*Numbers in the margin indicate pagination in the foreign text.

Only perhaps 10% of space transportation technology is generated under realistic space conditions. 90% of all remaining endeavors are carried out under the conditions found on Earth. From this fact it can be concluded that space transportation technology is only a specialized form of high technology. Therefore, research- or production-oriented activities in this field are not dependent upon location.

Involvement with space transportation technology has been directed so that a concurring policy of industrialization can be established. Retaining the original sites for technology development is a priority. To a greater extent, a "gap in knowledge" will be defined which can include the location of Berlin in planned research programs for the peaceful benefits of space transportation. The material objective for Berlin is the area: "Production of products under space conditions."

The main concerns of these scientific gains and of how these are translated into economic benefits are the questions of materials and raw materials science, manufacturing technology, pharmacology, energy technology, news and communications technology, mechanical engineering, and solar technology.

2. SPACE PROCESSING TECHNOLOGY

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2.1 THE SIGNIFICANCE OF SPACE PROCESSING TECHNOLOGY

/4

During the 1960s, the American Apollo space program was successfully carried out. The program had as its goal a manned space landing. The conclusion drawn from this breakthrough was the marked "technological gap" between the state of technology in the U.S. and in the other industrialized nations. This gap originated during the course of the concentrated efforts of 400,000 people who were directed toward a concrete goal. The

existing European technological gaps could, until this time, only be partially equalized. The new U.S. initiatives for construction of a permanent space station were to lead to further technological disparities. Because Europe, in comparison to the U.S., spends less than 10% of its resources in the area of space transportation, all efforts must be undertaken so that the existing technological gaps do not become greater.

The partiality of French presidents toward the EUREKA program and an inherently European space station originated as a consequence of this concern. On the basis of these circumstances and the continued efforts of the Soviet Union to make outstanding achievements in civilian and military space transportation, the West German government decided to elevate federal budget allocations for space transportation. The decision to participate in the million dollar COLUMBUS and ARIANE 5 projects was thus made.

Rapid technological development can be seen within the context of this political background. This development should serve the purpose of transforming the basic elements of nature--matter, energy, and information--as efficiently as possible. This transformation should result in an improvement in the quality of life for all. To this end, the boundaries of space transportation will be expanded. This concept becomes especially clear in the section on "generation and distribution of information." News, weather, navigation, and communication satellites as well as space probes demonstrate on a daily basis their contribution to the quality of life on Earth. In the coming decade, new activities in the area of energy production and distribution can take place with the help of space technology. Space technology especially allows for the environmentally desirable conversion of solar energy by means of orbiting space power stations. These stations will first become useful in an economic sense, if they are successful, by producing

the majority of building materials for the space power stations on the moon and in transporting them from the moon to the construction site. The evidence of transportation technology is at hand. The manufacture of space-specific products on an experimental basis aboard the spacelab has already begun and will be intensified under German participation. Because there are also commercial interests involved, Berlin should not falter at the onset of these developments.

In summary, it can be ascertained that there is scarcely another field of technology which requires such a high degree of interdisciplinary research as space transportation. The obstacles to be overcome are not only limited to technical problems. Biological, medical, economic, judicial, and political questions, all of which are related to technical problems, are just as important. In this sense, space transportation has a major function. The discipline of space transportation should be regarded as the nucleus of high technology. With this in mind, the production of energy and raw materials in non-terrestrial environments will play a special role.

2.2 CLASSIFICATION OF THE SPECIALIZED FIELDS OF SPACE PROCESSING TECHNOLOGY

The quality of life for people on the planet Earth is dependent upon the obvious connection between the basic elements (i.e. matter, energy, and information) and products which will satisfy the needs of the population without burdening their environment to an intolerable degree. Space technology can make substantial contributions to all three of the areas specified above. When one keeps in mind the "supply" and "distribution" functions, then the various courses of action outlined in Table 1 in the Appendix gain meaning.

2.2.1 The Processing and Distribution of Raw Materials (Course of Action I)

In Course of Action I, the capacities and interests of production-oriented research institutes (i.e. automation, robotics, special materials, special chemicals, and pharmacology) have been cultivated because of the ramifications of processing raw materials in extraterrestrial environments. For the same reason, the interest of the Institute for Geological Sciences and other possible industrial partners has been aroused. Processing raw materials in space gains special meaning in the event of the construction of a permanent moon station. This construction is proposed for immediately after the turn of the century.

(Reference: M.B. Duke, P.W. Keaton, W.W. Mendell, Report of The Lunar Base Working, April 23-27, 1984, LALP-84-43, August 1984.)

2.2.2 Transport of Material Goods and Personnel (Course of Action II)

The U.S. space shuttle is a representation of the first generation of reusable space transport systems. Up until the mid-1990s, improved systems are to be expected. The Technical University of Berlin (TUB) has made design proposals which anticipate reducing specific transportation costs in the Cis-Lunar region by at least one order of magnitude--with a corresponding market development of up to two orders of magnitude. With this development, commercially operating space transportation was successfully projected into the realm of real possibility. EUROPA, the European space agency, participated in this development with the ARIANE 5 (Ariane launch vehicle) and the projects HERMES and HOTOL. The specialized area of rocket technology/space transportation systems at the TUB adequately covers all the initiatives possible in Berlin in this field of activity. Contributions in the area of systems simulation as well as theoretical and experimental analysis of space laser generation are very possible.

2.2.3 Energy Production and Transformation (Course of Action III)

The transformation of energy in space is a key question for all extraterrestrial projects and can also become important for the Earth's energy conservation in the first half of the next century. Due to the unforeseen size of this market, the technological progress of this type of application of space technology must be observed with great care. Progress must be supported and organized into selective areas. The Department of Electrical Engineering of the TUB, the electric power industry, and the Institute for Physics Research are potential partners.

2.2.4 Transportation of Energy in Space (Course of Action IV)

The wireless transport of energy, which found its application in radar transmission in the last decade, is of great technological significance for future space power stations. These stations must transform solar energy into electrical energy and must send it to the user (on the Earth's surface). As alternatives, the use of lasers for the transport of energy is also coming into question. The laser's dependence on weather and its hitherto lack of efficiency make it appear to be more suitable for the transport of energy between producer and user in extraterrestrial environments than for the transport of energy to Earth. There are, to be sure, numerous electric power companies which could be interested in a collaboration in the solution of such problems, similar to the way in which the research institutes of the universities of Berlin were interested.

2.2.5 Information Acquisition

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Information acquisition through space vehicles and their sensors is already occurring today on a large scale. Over 3,000

satellites have already been launched from this planet! The total amount of information increases annually by about one order of magnitude and causes significant processing problems, which, for example, also appear with Earth-reconnaissance satellites involved in raw material acquisition. More TUB and FUB institutes are interested in information acquisition via satellite and have close contacts with manufacturers and investors. The European Space Agency (ESA) also has one of their focal points here. There will be possibilities in the future for it to participate in this development.

2.2.6 Distribution of Information (Course of Action VI)

Today, in this field of endeavor, millions of pieces of information are exchanged. A large number of national and international news satellites are in operation. In the near future, Berlin will also take part in this communication network through a receiving station in a government post in Wannsee. New technologies for larger, technically and economically efficient systems are in the development stage. In the future, these technologies will also dynamically shape this market. Legal questions concerning space traffic (frequency of travel and position) play a significant role here, so that economic and legal as well as technical problems must be solved. Solving these problems will involve frequent possibilities for cooperation.

2.3 POINTS OF DEPARTURE FOR RESEARCH PROJECTS

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Areas of Difficulty at the TUB

- Systematic understanding of the opportunities and risks of space manufacturing in the form of quantitatively supported data.

- Development of alternative scenarios for the future development of space processing with special regard to the European interests for the selection of suitable economic goals for Berlin.
- Simulation of a logical system for the construction and operation of space manufacturing locations with the goal of early availability, greater economic acceptance, and market profitability.
- Experiments concerning provisions for efficient preparation of pharmaceuticals in near-Earth orbits.
- Anthropological considerations in the construction of larger structures and installations in space.
- The dynamics of very large structures in Earth orbits and the development of methods and techniques to control position and orbit.
- Design of an experimental program for managing the yields and possibilities of solar energy in space to be used for the purpose of space manufacturing and transportation.
- Development of a process for the manufacture of solar cells under extraterrestrial conditions with the purpose of targeting current markets.
- Analysis of laser power as the transport tool for the orbital infrastructure based on space power stations.
- The development of a procedure for production of oxygen from lunar minerals through solar power.

Areas of Difficulty for the Free University of Berlin

- Development and testing of appropriate measurement equipment, such as electrometers, monochromatic illuminators, mass spectrometers, and laser spectrometers, for their introduction into space environments.
- Crystallization of biochemical macromolecules in a weightless environment:
 - 5S rRNA, 5S rRNA: protein complexes
 - Ribosomes
 - DNA fragments and DNA protein complexes
 - Acetylcholine and nicotine receptors
 - Oligosaccharides and oligopeptides
- Investigation of electrically conductive materials (intermolecular bonds and polymers) which are preserved by lowering their melting points or by reconstituting them under reduced gravity. Comparison of solid matter structures and electrophysical characteristics with specimens having the same chemical composition, but with terrestrial origins.
- Utilization of Landsat data for mining minerals, mapping land use, exploring mineral deposits and forecasting earthquakes.
- Development of methods for automatic processing of visual data for pattern recognition and kinetics analysis.
- Design and execution of physiological, medical and biological experiments in microgravity applications. Utilization of previously existing simulation designs from the FUB for treatment of physiological and endocrinological problems arising in an orbiting environment.

- Establishment of a program for the development of analytical methods in microgravity (electrophoresis, crystal growth) to prepare for production of biological substances.
- Electrical power and positioning systems for their applications in space.
- Characterization and management of cryogenic fluids under extraterrestrial conditions.

2.4 INTERNATIONAL ACTIVITIES IN THE AREA OF SPACE PROCESSING /8

Numerous activities, particularly in the United States, point to future gains in the area of space processing.

- A hearing on this theme took place before the "Space Progress and Applications" subcommittee of the U.S. Committee on Science and Technology. At this meeting, Mark R. Oderman, Vice-President of the Center for Space Policy, gave the newest tax assessment for the year 2000. This assessment can be attributed to the expected returns on space transportation. (Compare Table 2 in the Appendix).

These numbers only point out the commercial aspect of space transportation. The military expenditures on space transportation are not even included! (Reference: Aviation Week and Space Technology, July 8, 1985, p. 91.)

- The American governing authority on space transportation, NASA, has upheld 21 proposals for construction of institutes for advancement of the commercial application of space transportation. These proposals should be pursued as joint projects of the government, the economic

community, and the universities. NASA has intended to subsidize three to six such centers at chosen universities, making contributions of up to one million dollars for a period of up to five years. These centers will support, prepare, and assist applications such as single crystal manufacture, biotechnology, material production, earth reconnaissance, and information transmission. (Reference: Aviation Week and Space Technology, July 8, 1985, p. 13.)

- Since 1977, a special seminar entitled SPACE MANUFACTURING has taken place at Princeton University (U.S.) every two years with the support of the American Institute of Aeronautics and NASA. Five volumes of special publications have already been produced.
- The U.S. National Bureau of Standards has sold the first products manufactured during space shuttle flights in space to industrial firms and other institutions. These products were small latex spheres with diameters of ten microns. They are needed for calibration of highly sensitive instruments and can only be manufactured to this perfection under extraterrestrial conditions. These spheres are sold in 5-ml containers for up to \$384.00 U.S. per container. There are approximately 30 million spheres in each container. (Reference: Aviation Week and Space Technology, July 22, 1985, p. 229.)
- On June 17, 1985, a literature search of NASA data banks for the key words SPACE MANUFACTURING led to a listing of 280 publications with corresponding abstracts. This high number shows that an abundance of product ideas and knowledge already exists today. It would be beneficial, with a view to the Berlin economy, to make good use of this knowledge.

3. EXISTING POINTS OF DEPARTURE FOR RESEARCH IN BERLIN

/9

3.1 THE DEVELOPMENT OF SPACE TRANSPORTATION IN BERLIN

/10

Space transportation in Berlin began in 1928, when stage manager Fritz Lang brought physics professor Hermann Oberth to Berlin as a consultant from the Siebenbürger school. The TFA film "Woman on the Moon" was made in 1928-29, and it required a specialist. Oberth had already published his book "Roads to Spacecraft Transportation" and appeared to be the man whose ideas were correct. Lang gave him the task of launching a rocket on the day of the premier performance. The film opened in Berlin on October 15, 1929, but the rocket was not completed. Nevertheless, the physical-technical government establishment acknowledged to professor Oberth and his assistant Wernher von Braun that his rocket engines worked perfectly.

Although Oberth eventually returned to Siebenbürger, his colleagues founded the rocket launch pad in Berlin under the leadership of Rudolf Nebel on September 27, 1930. This launch pad was located where the Tegel airport is today. In 1931-32, there ensued a series of ground and flight experiments with an intensity found nowhere else in Europe. Berlin was, at that time, the center for rocket research in Europe.

Wernher von Braun took his degree in 1934 with his work on rocket engines and was at the same time the head of the rocket test area in Kummersdorf next to Berlin. Later he constructed the test stations and flight strips in Peenemünde. However, control of German rocket development remained in the hands of Dr. Dornberger (chief army commander) until the end of the war in Berlin.

After the end of the war there was a forced pause until 1963, when Dr. Eugen Saenger, a well-known space pioneer and

trailblazer for the space shuttle, became professor of space transportation technology at TUB. This was the first professional chair for the specialized area of space transportation technology in Germany and in Europe as a whole. Professor Saenger died in 1964 after only one year at TUB. His successor, Dr. Ing H.H. Koelle, a student of Saenger and Wernher von Braun, took over the chair and the Institute for Space Transportation Technology. In 1971, within the new order at the TUB, space transportation technology was integrated with the Institutes for Air Transportation in what is known today as the Institute for Air and Space Travel.

3.2 THE TECHNICAL UNIVERSITY OF BERLIN

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The Institute for Aeronautics and Space Transportation at the TUB employs 130 people, of whom 12 are university professors (as of 1985).

The entire curriculum in the area of space transportation is shown in a block diagram in Table 3 of the Appendix. It is the most comprehensive curriculum in this field which can be found at a European university.

In previous years at the Institute for Aeronautics and Space Transportation, several experiments geared toward extraterrestrial production and the logical support of these experiments were carried out. The results of these experiments were calculated. At the other TUB institutes, especially in the area of materials sciences, appropriate experiments were prepared and performed. These were also conducted within the SPACELAB program with the support of the BMFT.

The following TUB institutes can make specialized contributions to space manufacturing:

Institute for:

- Applied Geophysics, Petroleum Science, and Storage Research (1638)
- Inorganic and Analytical Chemistry (0530)
- Manufacturing Science (1135)
- Astronomy and Astrophysics (0434)
- Mining Sciences (1633)
- Biochemistry and Molecular Biology (0633)
- Biophysics and Physical Chemistry, Max Volmer Institute (0632)
- Chemical Engineering (1032)
- Electrical Engineering (1936)
- Electronics (1932)
- Vehicle Technology (1233)
- Solid State Physics (0431)
- Surveying and Photography (0734)
- Geology and Paleontology (1636)
- High-Frequency Technology (1935)

Hermann Foettinger Institute for Fluid Dynamics and Thermodynamics (0931)

Iwan N. Stranski Institute for Physical and Theoretical Chemistry (0630)

Institute for:

- Nutrition (1331)
- Nuclear Technology (1031)
- Mining and Metallurgical Engineering (1634)
- Measurement and Calibration Technology (1030)
- Metals Research (1731)
- Metallurgy (1730)
- Mineralogy and Crystallography (1637)
- Non-metal Raw Materials (1732)
- Organic Chemistry (0531)
- Radiation and Nuclear Physics (0435)
- Technical Chemistry (0631)
- Technical Information Science (2030)

- Thermodynamics and Design Technology (1033)
- Materials Science (1733)
- Machine Tools and Fabricating Technology (1134)

3.3 THE FREE UNIVERSITY OF BERLIN

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Extensive knowledge and experience in conducting scientific experiments under space conditions are available at the various departments of the Free University of Berlin [FUB]. Since the founding of the Institute for Physiology (FB Fundamental Medicine) 60 years ago, questions concerning the effects of space conditions on physiology are continually being addressed. In collaboration with the FUB, physiological and medical experiments are executed during spacelab flights and during D1-missions. In the field of physics, landmark discoveries ensued in the area of low temperature technology. These discoveries were successfully incorporated into various space projects. A large number of research groups in the field of geological sciences have, for a long time, employed many different methods and tried to draw meteorological and geophysical conclusions from space exploration of the Earth's surface. To confront the growing volume of space technology in the area of geological sciences, a new research group will be organized in the near future.

The following institutes at the FUB are of importance due to their research contributions:

The field of geological sciences:

Institute for:

- Applied Geology (WE 2)
- Geophysical Sciences (WE 4)
- Geography (WE 6)
- Meteorology (WE 7)

The field of chemistry:

Institute for:

- Organic Chemistry (WE 2)
- Physical Chemistry (WE 3)
- Crystallography (WE 5)
- Biochemistry (WE 6)

The field of fundamental medicine:

Institute for Physiology (WE 2)

The field of physics:

Institute for Atomic and Solid Body Physics (WE 1)

4. PLANNED POINTS OF DEPARTURE FOR RESEARCH IN BERLIN /13

The scientific capabilities outlined under Section 3 /14
entitled "Existing Points of Departure for Research in Berlin"
still do not compose a complete list of the available potential
in Berlin.

In addition to the points of departure for research at both
Berlin universities, other scientific potentials available in
non-university environments can be accessed.

In conjunction with this operation, a broader plan, along
the lines of an economic analysis, must be considered. This plan
must become part of the "Space Processing Technology" work.
Private economic institutions have proven to be an especially
important instrument for improvement of cooperation between
science and business. In the legal form of a GmbH, these
institutes cooperate and are in close collaboration with one or
two large Berlin universities.

For this reason, the founding of an institute in Berlin for "Space Processing Technology GmbH" would be an important step forward in research.

4.1 INSTITUTE FOR SPACE PROCESSING TECHNOLOGY GmbH (IEP) /15

The goal and objective of the Institute is to take on the function of acting as a "bridge" between science and business in the area of space technology. These technologies seem well suited to lead to marketable products in the next decade.

Crucial points in these endeavors will probably lie in the areas of materials science, pharmacology, energy technology, communications and news technology, mechanical engineering, solar technology, and laser technology. There are good possibilities for undertaking research in these areas in Berlin; however, the research is of international significance.

The concrete undertakings will be:

- Testing product ideas for space technology with regard to their physical and technical feasibility.
- Analysis of product ideas for space technology with regard to their economic market prospects.
- Conceptualization of extraterrestrial processing methods and plants.
- Evaluation of the consequences of technology with the introduction of the space-supported production of energy and material products.
- Analysis of the possibilities of extraterrestrial raw materials processing to relieve the terrestrial environment.

- Preparation and implementation of pertinent experiments within the SPACELAB and COLUMBUS programs.
- Research by manufacturers on space manufacturing designs, and,
- Education and training of specialists in the area of space manufacturing.

In a situation of national and international competition, these projects will promote a high amount of flexibility, reaction capability, and the ability to recognize the correct possibilities.

Well-known businesses which were previously not represented in Berlin have become evident in concrete form with their interest in collaborating with this Institute for Space Processing Technology. The plan of two business leaders is to coordinate so that one will be stronger in science and the other in production.

It is certain that, with the founding of the Institute during 1986, concrete work in the field of space processing can begin.

5. APPENDIX

TABLE 1. The contributions of space technology to the creation and distribution of the basic elements of matter, energy, and information.

Basic Elements	-----Function-----	
	Procurement Processing	Distribution Expansion Transport
Matter	I. Products made from terrestrial raw materials but produced in a space environment.	II. Transport of goods and personnel by means of chemical- and electrical-powered space transport systems between traffic junctions.
	Products made from extraterrestrial raw materials and produced in a space environment.	
Energy	III. Transformation of solar energy into electrical or thermal energy by means of photo-voltaic or solar thermal installations.	IV. Transport of energy by means of laser and microwave transmitter and user receivers.
	V. Acquisition of information by means of sensors aboard satellites and other space vehicles (reconnaissance, weather, and research satellites).	VI. News, television transmission, navigation satellites, and corresponding ground installations.

TABLE 2. Possible annual exchange totals in space technology.

Area	Expected Exchange in Millions of U.S. Dollars	
	<u>Minimum</u>	<u>Maximum</u>
New Satellites	8.8	15.3
Orbital Services	0.6	2.8
Space Transportation	0.2	2.4
Space Manufacturing	2.0	17.9
Ground Stations, Installations Payload Maintenance	4.1	10.4
<hr/>		
Expected annual total in space technology	15.7	48.8
(2000)	Billions of US\$	

TABLE 3. Curriculum offerings in the area of space transportation at the Technical University of Berlin.

Space Flight Mechanics	Parachute Technology	Satellite Technology	System Technology
8 SWS in WS	8 SWS in WS	8 SWS in SS	8 SWS in WS
Control of Spaceflight Conditions	Space Power Generation	Satellite Design	Application of Systems Tech- nology
4 SWS in SS	8 SWS in SS	8 SWS in WS	4 SWS in SS
Special Areas Location and Navigation			Quantitative Systems Analysis
4 SWS in SS			4 SWS in SS
	Space Trans- portation Planning	<u>planned:</u> Space Transpor- tation Management	
	8 SWS in SS		

SWS - Semester-week
hours

SS - Summer semester

WS - Winter semester